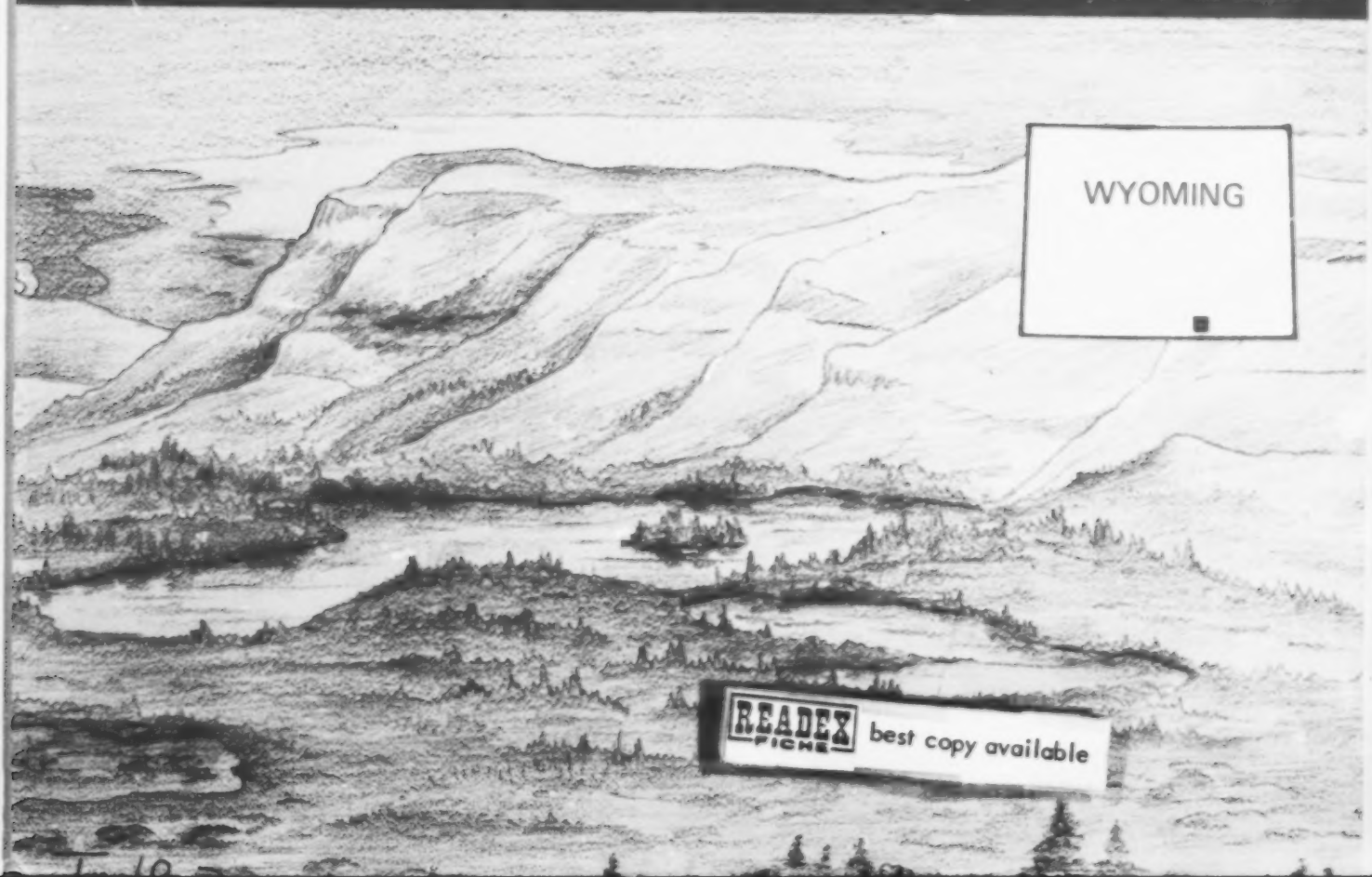
1757-E

Mineral Resources of the Prospect Mountain Wilderness Study Area, Carbon County, Wyoming

U.S. GEOLOGICAL SURVEY BULLETIN 1757–E



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Chapter E

Mineral Resources of the Prospect Mountain Wilderness Study Area, Carbon County, Wyoming

By EDWARD A. DU BRAY, VIKI BANKEY, and RANDALL H. HILL
U.S. Geological Survey

GEORGE S. RYAN
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1757

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHERN WYOMING

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Prospect Mountain Wilderness Study Area (WY-030-303), Carbon County, Wyoming.

CONTENTS

Abstract E1
Summary E1
Character and setting E1
Identified mineral resources E1
Mineral resource potential E2
Introduction E2
Investigations by the U.S. Bureau of Mines E3
Investigations by the U.S. Geological Survey E4
Appraisal of identified resources E4
Assessment of potential for undiscovered resources E4
Geology E4
Geochemistry E5
Geophysics E6
Mineral and energy resources E8
References cited E8
Appendix E9

FIGURES

1. Index map showing location of the Prospect Mountain Wilderness Study Area E2
2. Map showing mineral resource potential and generalized geology for the Prospect Mountain Wilderness Study Area E3
3. Residual aeromagnetic anomaly map of the Prospect Mountain Wilderness Study Area and vicinity E6
4. Uranium equivalent (eU) values for the Prospect Mountain Wilderness Study Area and vicinity E6
5. Thorium equivalent (eTh) values for the Prospect Mountain Wilderness Study Area and vicinity E7
6. Potassium (K) values for the Prospect Mountain Wilderness Study Area and vicinity E7

Mineral Resources of the Prospect Mountain Wilderness Study Area, Carbon County, Wyoming

By Edward A. du Bray, Viki Bankey, *and*
Randall H. Hill
U.S. Geological Survey

George S. Ryan
U.S. Bureau of Mines

ABSTRACT

The Prospect Mountain Wilderness Study Area (WY-030-303), located about 20 miles east-southeast of Encampment, Wyoming, contains 1,145 acres whose mineral endowment was jointly studied by the U.S. Bureau of Mines and the U.S. Geological Survey in 1987. There are no identified resources in the study area. Resource potential for undiscovered metallic commodities and for industrial minerals is low. The study area has no potential for undiscovered energy resources, including oil and gas, coal, geothermal resources, and uranium.

SUMMARY

Character and Setting

The USGS (U.S. Geological Survey) and the USBM (U.S. Bureau of Mines) studied the mineral resource potential of 1,145 acres in the Prospect Mountain Wilderness Study Area (WY-030-303), Carbon County, Wyo., at the request of the BLM (U.S. Bureau of Land Management). In this report, the area studied is referred to as the "wilderness study area" or the "study area." Field studies of the study area were conducted during the summer of 1987 by USBM geologists and by USGS geologists, geochemists, and geophysicists.

Encampment, Wyo., about 20 mi (miles) west-northwest of the Prospect Mountain Wilderness Study Area, is the nearest sizable town (fig. 1). The study area is accessible on its west side from graded unpaved roads that intersect Wyoming State Route 230. The study area is located on the gently sloping western flank of the Medicine Bow Mountains. Elevations in the study area range between 7,400 and 8,400 ft (feet). The study area is underlain by Middle Proterozoic (see geologic time chart in Appendix) gabbro, granite, and hornblende gneiss. Hornblende gneiss occurs throughout the southern part of the study area, whereas gabbro and granite occur in the northern part. Pegmatite dikes intrude all other rocks.

Identified Mineral Resources

There are neither mining districts nor any records of production from ore deposits in the study area. (In this

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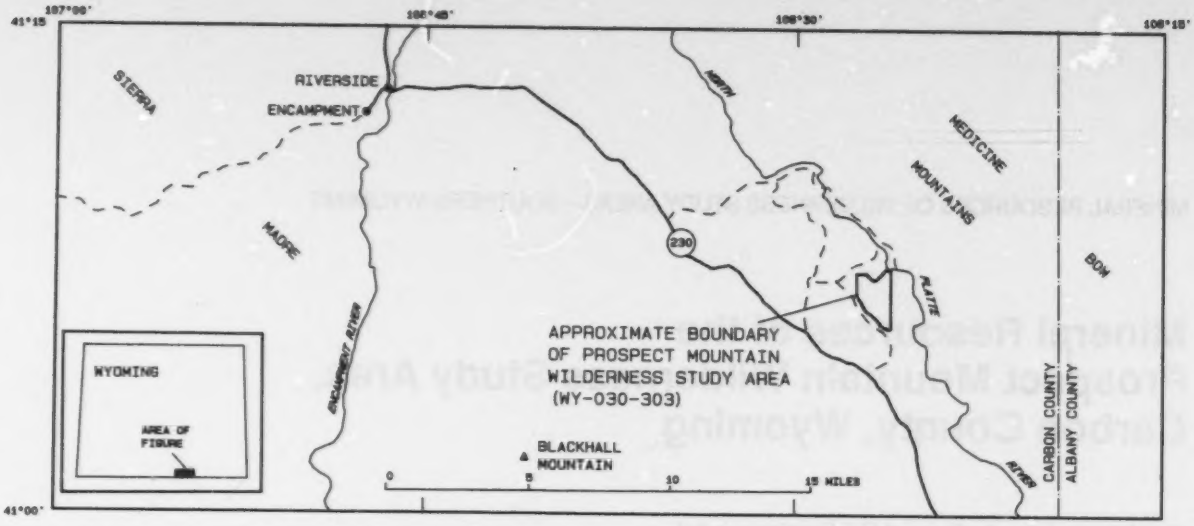

Figure 1. Index map showing location of the Prospect Mountain Wilderness Study Area, Carbon County, Wyo. Dashed lines are selected unpaved roads.

report, the term "deposit," unmodified, does not connote economic value.) No mineral resources were identified by the USBM in the Prospect Mountain Wilderness Study Area. Three samples collected by USBM geologists at a prospect pit and caved adit on the northern boundary of the study area contained minor amounts of gold, silver, and copper and lower concentrations of other elements in a limited area; assay results from a pegmatite sample indicate the occurrence of a minor amount of silver. The study area is underlain by crystalline rocks, which do not host hydrocarbon accumulations; there are no oil and gas leases in the study area. No sand and gravel deposits occur in the study area.

Mineral Resource Potential

The geologic environment in the Prospect Mountain Wilderness Study Area is favorable for the occurrence of certain types of metallic mineral deposits, but the insignificant quantity of mineralized rock, lack of major geochemical anomalies not attributable to differences in lithology, and absence of favorable geophysical characteristics indicate that mineral resource potential in the study area is low for all metals (fig. 2).

Energy resources, including oil and gas, coal, uranium, and geothermal resources, are unknown in the study area. The crystalline rocks that underlie the study area are neither source nor reservoir rocks for oil, gas, or coal, nor is the structural setting of the study area appropriate to undiscovered resources of these commodities. The absence of uranium-anomalous values in the geochemical database and the failure of the aeroradiometric survey to identify anomalous uranium concentrations indicate no potential for uranium deposits in the study area. The absence of geothermal phenomena and the old age of the rocks in the study area indicate that there is no potential for geothermal energy resources. Accordingly, the study area has no potential for energy resources (fig. 2).

Available geologic, geochemical, and geophysical data indicate low potential for undiscovered industrial mineral resources in the study area (fig. 2).

INTRODUCTION

The Prospect Mountain Wilderness Study Area is about 20 mi east-southeast of Encampment, Wyo., the nearest sizable town (fig. 1). The study area, a gently rolling, dissected upland covered by grasses and sage, is on the sloping western flank of the Medicine Bow Mountains and is accessible on its west side from graded unpaved roads that intersect Wyoming State Route 230. Travel in the study area is by way of a few rough jeep roads and on foot. Valleys and the highest north-facing slopes support stands of aspen and fir trees. The North Platte River flows north in a 1,000-ft-deep canyon just east of the study area.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource

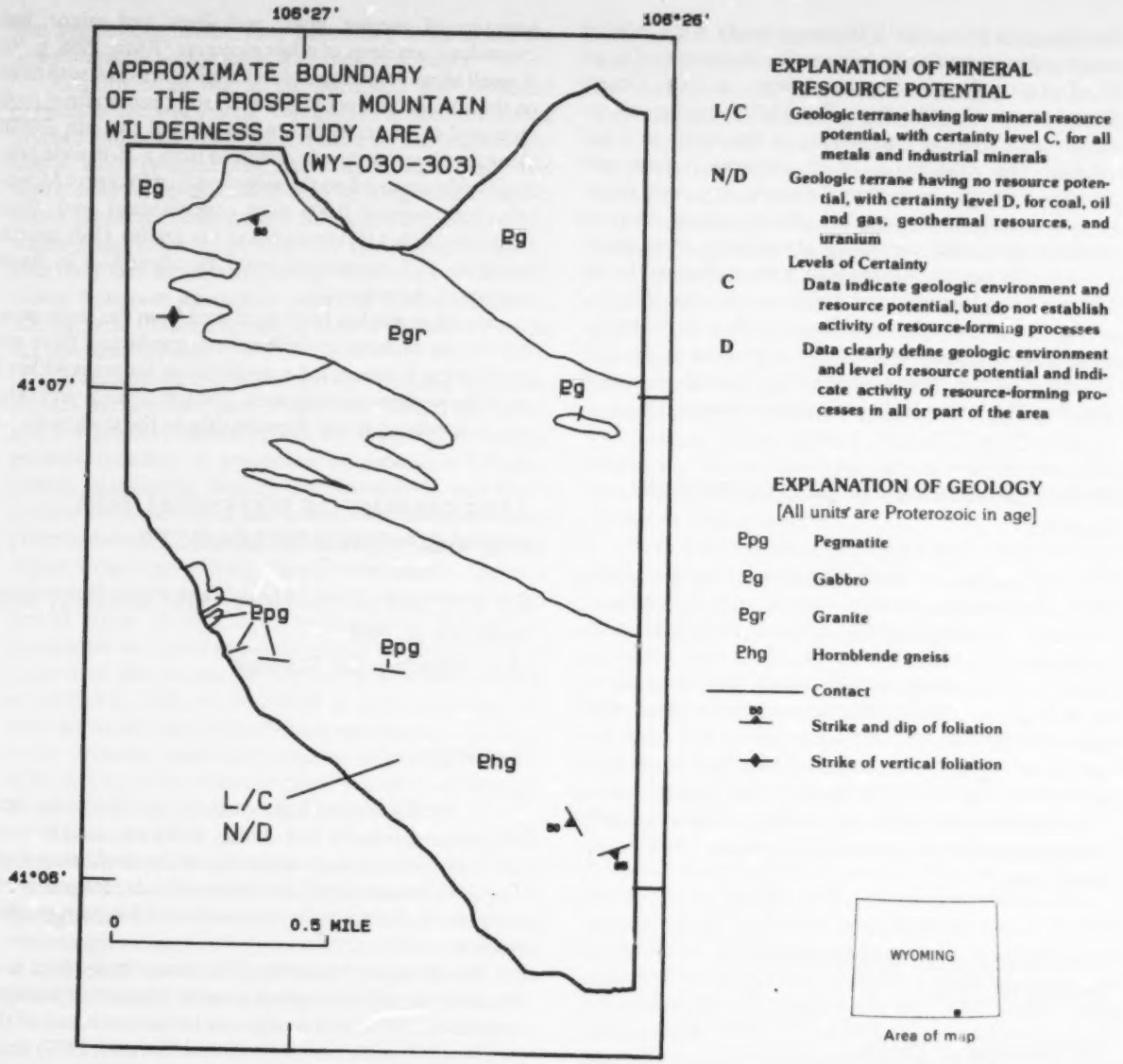
106°27'
106°26'
APPROXIMATE BOUNDARY
OF THE PROSPECT MOUNTAIN
WILDERNESS STUDY AREA
(WY-030-303)
Pg
Pgr
Ppg
Phg
L/C
N/D
41°07'
41°06'
0
0.5 MILE
EXPLANATION OF MINERAL RESOURCE POTENTIAL
L/C Geologic terrane having low mineral resource potential, with certainty level C, for all metals and industrial minerals
N/D Geologic terrane having no resource potential, with certainty level D, for coal, oil and gas, geothermal resources, and uranium
Levels of Certainty
C Data indicate geologic environment and resource potential, but do not establish activity of resource-forming processes
D Data clearly define geologic environment and level of resource potential and indicate activity of resource-forming processes in all or part of the area
EXPLANATION OF GEOLOGY
[All units are Proterozoic in age]
Ppg Pegmatite
Pg Gabbro
Pgr Granite
Phg Hornblende gneiss
Contact
Strike and dip of foliation
Strike of vertical foliation
WYOMING
Area of map

Figure 2. Map showing mineral resource potential and generalized geology for the Prospect Mountain Wilderness Study Area, Carbon County, Wyo.

potential) of the study area and is the product of several separate studies by the USBM and the USGS. Identified resources are classified according to the system of the U.S. Bureau of Mines and U.S. Geological Survey (1980), which is shown in the Appendix of this report. Identified resources are studied by the USBM. Mineral resource potential is the likelihood of occurrence of undiscovered concentrations of metals and nonmetals, of unappraised industrial rocks and minerals, and of undiscovered energy resources (coal, oil, gas, oil shale, and geothermal resources). It is classified according to the system of Goudarzi (1984), which is shown in the Appendix of this report. The potential for undiscovered resources is studied by the USGS.

Investigations by the U.S. Bureau of Mines

USBM geologists reviewed mining, mineral lease, and mining claim information and other published material related to mineral resources and mining activities in and near

the Prospect Mountain Wilderness Study Area. Mining claim and master title plat information was reviewed in the BLM State Office in Cheyenne, Wyo., and the County Courthouse in Rawlins, Wyo. Two USBM geologists conducted a 2-day field examination in the study area and vicinity. The abundances of 32 elements in four rock samples collected in or near the study area were determined by inductively coupled plasma–atomic emission spectrometry; gold and silver abundances were determined by fire-assay. All analyses were performed by the Chemex Labs, Incorporated, facilities in Sparks, Nev., and selected results are shown in Ryan (1988, p. 8). Complete analytical data are available for inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, Colo.

Investigations by the U.S. Geological Survey

The assessment of the mineral resource potential of the Prospect Mountain Wilderness Study Area is based on data from many sources. Among these are geologic studies of the Sierra Madre and the Medicine Bow Mountains (Houston, 1961; Houston and others, 1978; du Bray, this report), geochemical studies by the USBM (Ryan, 1988) and the USGS (R.H. Hill, unpub. data, 1987); and interpretations of geophysical data, including aeromagnetic and aeroradiometric data (Viki Bankey, this report), Landsat Thematic Mapper data (Alta Walker, written commun., 1988), and telluric survey data (D.H. Hoover, written commun., 1988).

APPRAISAL OF IDENTIFIED RESOURCES

By George S. Ryan
U.S. Bureau of Mines

No recent mining activity was noted in the wilderness study area, although mining claim notices on file with the BLM indicate recent claims were located in and near the study area. One unreadable claim notice was found posted on a tree within the study area, but no claim posts nor signs of recent excavations, drill holes, or other exploration activities were found.

No mineral resources were identified in the wilderness study area. The walls and dump material of a prospect pit and caved adit on the northwestern side of Prospect Mountain are stained with copper carbonate and manganese oxide. Sample assays indicate the presence of small amounts of copper, gold, and silver and minor, but anomalous, amounts of other elements (Ryan, 1988, p. 8). A small shear zone exposed in the pit is covered with talus on the surface and could not be traced; mineralized rock appeared to be restricted to the pit and the adit driven along the shear. A sample collected from a 25-ft-wide pegmatite dike exposed on the ridge south of Prospect Mountain Peak assayed 0.006 oz/st (ounces/short ton) silver (approximately 1,000 times below ore grade). Only quartz, feldspar, and magnetite could be identified in hand samples of the pegmatite.

No oil or gas has been produced from the study area, nor has any exploratory drilling been conducted; there are no oil or gas leases or lease applications for areas within 2 mi of the wilderness study area. The soil cover is very thin, and no sand and gravel deposits exist in the study area.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Edward A. du Bray, Viki Bankey, and Randall H. Hill
U.S. Geological Survey

Geology

A small-scale geologic map of the Medicine Bow Mountains (Houston and others, 1978) was used to compile a preliminary large-scale map of the study area. Outcrops were examined for signs of mineralized rock. Samples of all rock units were collected for petrographic studies.

The Prospect Mountain Wilderness Study Area is in the Colorado Plateaus physiographic province (Bickford and others, 1986) and is adjacent to the south end of the Archean Wyoming craton (Hills and Houston, 1979) along the Cheyenne belt. The study area is underlain by Proterozoic gabbro, granite, and hornblende gneiss, which is locally intruded by pegmatite dikes. The Cheyenne belt is an inferred suture zone at the southern edge of the North American craton along which lithospheric material was accreted during Proterozoic time. The hornblende gneiss and to a lesser extent the granite and gabbro are foliated; their deformation is probably related to the compressional suturing event associated with accretion of the Colorado province to the Wyoming craton.

Granite pegmatite dikes are especially abundant in the hornblende gneiss. The dikes are unzoned and are principally composed of coarse-grained quartz and feldspar but also contain minor amounts of biotite, muscovite, gar-

net, and opaque oxides. They have sharp contacts and are approximately conformable with their host rocks.

Gabbro crops out in the northwest and northeast corners of the study area. The gabbro is fine to medium grained and weakly foliated and has a seriate texture. Unzoned, albite-twinned plagioclase occurs interstitially and forms anhedral grains (0.02–0.16 in. long) that compose about 55 percent of the gabbro. Subhedral hypersthene and augite grains (0.02–0.1 in. long) are approximately equally abundant and account for about 40 percent of the rock. About 5 percent interstitial, anhedral opaque oxides are also present. Chlorite occurs as narrow alteration rims on the pyroxene crystals.

Granite crops out in a northwest-trending zone that crosses the northern part of the study area. The coarse-grained granite, characterized by a weakly developed gneissic foliation, is composed of potassium feldspar, quartz, plagioclase, biotite, and hornblende and has a seriate texture. Abundant potassium feldspar forms gridiron-twinned, anhedral grains (0.2–0.4 in. long) that impart a vague porphyritic texture to the granite. Quartz is characterized by undulose extinction and occurs as anhedral grains (0.08–0.16 in. in diameter). Biotite and hornblende are about equally abundant and compose 5–10 percent of the granite. Subhedral, light-brown to dark-green biotite laths are 0.02–0.06 in. long, and anhedral, light-tan to dark-green hornblende aggregates are 0.02–0.1 in. in diameter. Accessory epidote in granular clusters 0.004–0.02 in. in diameter compose 1–2 percent of the rock. Trace amounts of apatite were also identified.

The hornblende gneiss is a plagioclase-amphibole rock, with quartz and epidote as accessory minerals, whose distribution is widespread throughout southern Wyoming. The gneiss is characterized by great textural and mineralogic variation. The gneiss in the study area consists of alternating bands of amphibole-rich gneiss and felsic gneiss, the amphibole-rich variety being predominant.

Geochemistry

In September of 1987, a reconnaissance geochemical survey was conducted to aid evaluation of the mineral resource potential of the study area. Rocks, stream sediments, and heavy-mineral concentrates derived from stream sediment were selected as the sample media for evaluation.

Five minus-60-mesh stream-sediment samples collected from alluvium of active streams and five corresponding heavy-mineral concentrates panned from stream sediment were selected as primary sample media. The sediments are presumed to represent a composite of the rock and soil exposed in the drainage basin upstream from the sample site. Chemical analysis of such stream-sediment samples provides data useful in identifying those basins that contain unusually high concentrations of elements that may be related to mineral occurrences. In addition, studies have shown that heavy-mineral panned concentrates derived from stream sediment are useful in evaluating arid-semiarid environments or areas of rugged topography, where mechanical erosion predominates over chemical erosion (Bugrov and Shalaby, 1975; Overstreet and Marsh, 1981). Heavy-mineral-concentrate samples provide information about the chemistry of a limited number of minerals present in rock material eroded from the drainage basin upstream from each sample site. Preparation of heavy-mineral concentrates from stream sediment results in a concentration of mineral assemblages that may contain ore-forming and ore-related minerals. The selective concentration of these minerals permits analytic determination of some elements that are not easily detected in bulk stream-sediment samples.

Four fresh and unaltered rock samples were collected from outcrops to provide chemical and mineralogic information for rocks exposed near stream-sediment sample sites. In addition, one mine-dump sample was collected to provide information concerning the composition of mineralized rock present in the study area. The actual areal extent of the influence of each rock type on the chemistry of individual stream-sediment and panned-concentrate samples is indeterminate, though the sampling program was designed to provide general information concerning the geochemical nature of the exposed lithologies.

The dry stream-sediment samples were sieved through 60-mesh stainless-steel sieves. The minus-60-mesh material was retained for analysis and pulverized with ceramic plates to at least minus-100 mesh prior to analysis. To produce the heavy-mineral concentrate, bulk stream sediment was first sieved through a 10-mesh screen. Approximately 25–30 pounds of the minus-10-mesh sediment was panned to remove most of the quartz, feldspar, organic material, and clay- sized material. These samples were then air dried, passed through a 30-mesh sieve, and separated into light and heavy fractions by means of bromoform (heavy liquid, specific gravity 2.86). The light fraction was discarded. The material of specific gravity greater than 2.86 was separated into three fractions (highly magnetic, weakly magnetic, and nonmagnetic) by means of a modified Frantz Isodynamic Magnetic Separator. The nonmagnetic fraction was hand ground and retained for emission spectrographic analysis. Rock samples were crushed and pulverized to at least minus-100 mesh with ceramic plates prior to analysis. Rock, stream-sediment, and nonmagnetic portions of the heavy-mineral concentrates were analyzed for 35 elements by means of a semiquantitative, direct-current arc emission spectrographic method (Grimes and

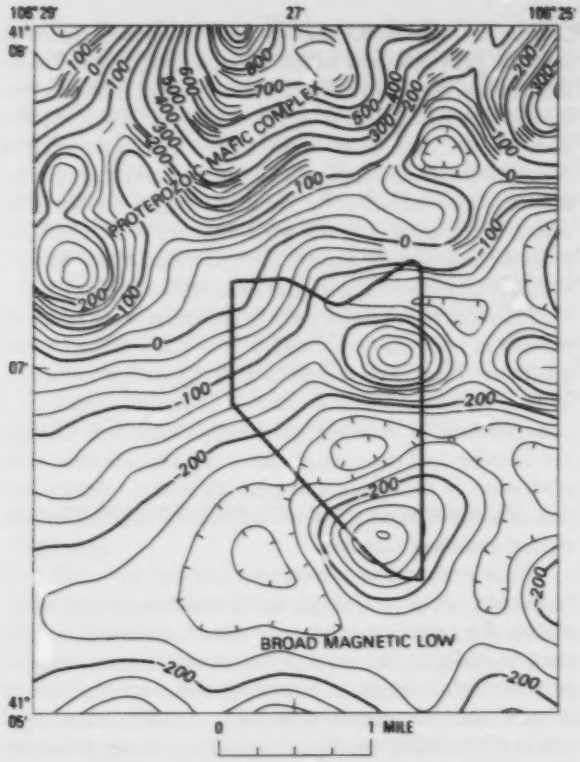

Figure 3. Residual aeromagnetic anomaly map of the Prospect Mountain Wilderness Study Area and vicinity, Carbon County, Wyo. Heavy line is approximate boundary of wilderness study area. Contour interval 25 nanoteslas; hachures indicate area of closed low.

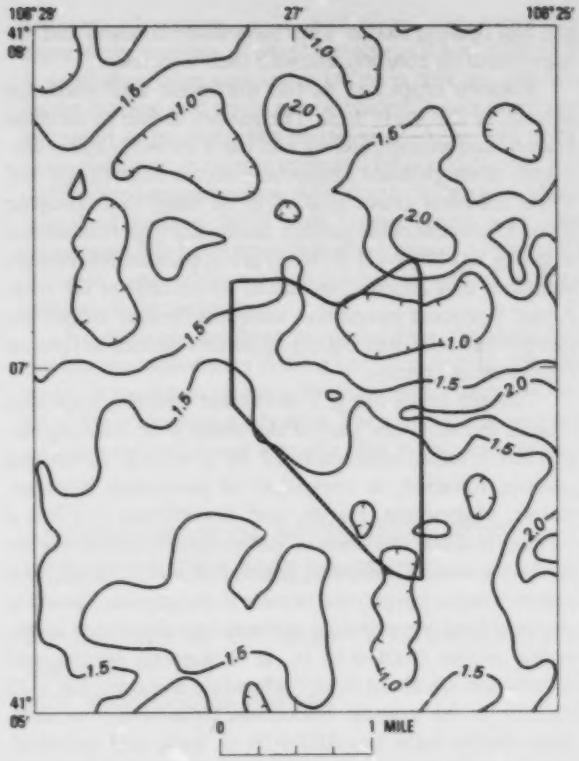

Figure 4. Uranium equivalent (eU) values for the Prospect Mountain Wilderness Study Area and vicinity, Carbon County, Wyo. Heavy line is approximate boundary of wilderness study area. Contour interval 0.5 parts per million; hachures indicate area of closed low.

Marranzino, 1968); abundances of palladium and platinum in the concentrates were also determined by this method.

Threshold values, defined as the upper limit of normal background values, were determined for each element by inspection of frequency-distribution histograms for all sample media. The composite mine-dump rock sample was not included in construction of the histograms. Concentrations of elements greater than the threshold values are considered anomalous and worthy of consideration as possible indicators of mineralized rock.

The primary criterion for delineating an area as anomalous is the presence of multi-element geochemical anomalies clustered within a restricted geographic region. Follow-up studies should, however, include isolated anomalous sample localities with geographically extensive, geochemically anomalous areas because the scale of sampling conducted for this study is so small that moderate-sized deposits could be indicated by single sample sites, or not be apparent at all. In addition, this study is a surface study and may not reflect the presence of mineralized rock at depth.

A very weakly anomalous area is present in the northwestern part of the study area, where the drainage basin contains granite in contact with gabbro. The anomalous heavy-mineral concentrate contains 150 ppm (parts per million) copper, 150 ppm chromium, 50 ppm gallium, and 70 ppm nickel. These concentrations may reflect the presence of dense minerals (such as chromite) that are characteristic accessory phases in mafic and ultramafic rocks, such as those exposed in the drainage basin represented by this sample. The abundance of these minerals in this area may be somewhat enhanced in the border phase of the gabbro exposed at its contact with granite due to segregation layering and accumulation of dense minerals at the margins of mafic and ultramafic intrusive bodies in many places.

Geophysics

A detailed aeromagnetic survey of the wilderness study area and vicinity was flown in 1979 (as part of the Na-

tional Uranium Resource Evaluation) by a fixed-wing aircraft at a nominal ground clearance of 400 ft. Flight traverses were oriented north-south and spaced 0.25 mi apart; these specifications provide 60 percent coverage of surface sources and 100 percent coverage of sources buried below 200 ft depth. After correction for diurnal effects and tie-line discrepancies, the International Geomagnetic Reference Field was removed. The resulting residual magnetic data were compiled and contoured by the contractor (Bendix Field Engineering Corporation, 1983) to produce a regional aeromagnetic map. The map is useful in geologic interpretations of the region that contains the study area; a subset of the data was used to aid interpretation of the geology in the study area.

Aeromagnetic data (fig. 3) may be useful in delineating concealed intrusive rocks that could be associated with mineral deposits. Two magnetic highs, in the southern and northeastern parts of the study area, respectively, may indicate the presence of intrusions. The northeastern anomaly is probably caused by the gabbro outcrop that is part of a Proterozoic mafic complex north of the study area. This mafic complex is characterized by many high-amplitude, high-frequency positive magnetic anomalies (fig. 3). The southern anomaly is associated with hornblende gneiss that is continuous across the study area and extends well beyond the anomaly. A magnetic high lies in the center of a much broader magnetic low that separates it from other positive magnetic features. Mapped geology does not suggest a source for the magnetic low (such as a less magnetic granite). The broad low is probably too large to be the result of alteration around a body inferred to be the source of the imbedded magnetic high.

Aerial gamma-ray spectroscopy is a radiometric technique that provides an estimate of the near-surface (depth 0–20 in.) concentrations of uranium (U), thorium (Th), and potassium (K) and is used in exploration for uranium deposits. The occurrence of radioactive quartz-pebble conglomerate in the Medicine Bow Mountains and Sierra Madre necessitated a detailed aeroradiometric survey in this region to determine the extent and abundance of

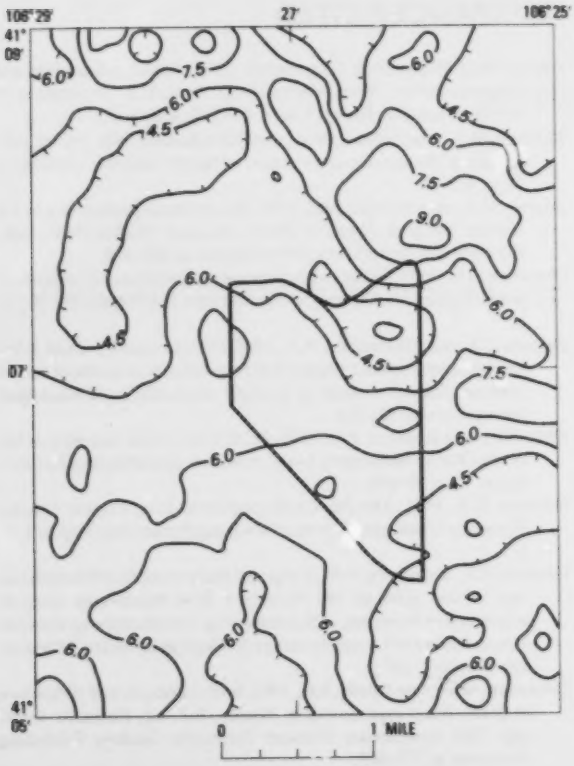

Figure 5. Thorium equivalent (eTh) values for the Prospect Mountain Wilderness Study Area and vicinity, Carbon County, Wyo. Heavy line is approximate boundary of wilderness study area. Contour interval 1.5 parts per million; hachures indicate area of closed low.

Figure 6. Potassium (K) values for the Prospect Mountain Wilderness Study Area and vicinity, Carbon County, Wyo. Heavy line is approximate boundary of wilderness study area. Contour interval 0.5 percent; hachures indicate area of closed low.

uranium. Aeroradiometric data for the study area were obtained from traverses flown in 1979 by contractors working for the U.S. Department of Energy as part of the National Uranium Resource Evaluation (Bendix Field Engineering Corporation, 1983). The traverses are along north-south lines spaced 0.25 mi apart and have a nominal ground clearance of 400 ft. These specifications are sufficient to achieve 60-percent ground coverage (figs. 4–6). The U and Th values are "equivalent" values (eU and eTh) to account for possible disequilibrium in the decay series for those elements.

Generally, silicic rocks are more radioactive than mafic rocks. This holds true in the study area, where the granitic rocks are associated with increased levels of uranium (U), thorium (Th), and potassium (K). Values range from 1.0 to 2.0 ppm eU, 4.5 to 7.5 ppm eTh, and 1.0 to 3.0 percent K. Apart from the slightly increased concentration found where granitic rocks occur, the radio-element values are at or below background levels.

Landsat Thematic Mapper data can be used to identify indications of mineralized or altered rock exposed at the Earth's surface. Data for seven spectral bands, analyzed individually, as composites, and as ratios, do not indicate the presence of mineralized or altered rock in the study area (Alta Walker, written commun., 1988).

Telluric surveying is a method whereby the electrical resistivity of rock present at various depths below the ground surface can be determined. The method can be used to explore for changes in resistivity that may indicate altered or mineralized rock. Resistivity variation along two traverses in the study area is within the range expected as a function of lithologic variation; the method does not indicate the presence of unusually altered or mineralized rock.

Mineral and Energy Resources

Mineral resource potential for all metals in the study area is low. The geologic setting of the study area is favorable for various types of metalliferous deposits (including deposits of platinum-group elements associated with mafic and ultramafic rocks and pegmatite-hosted deposits), but supporting evidence and additional features indicative of favorablity for the occurence of deposits in the study area are absent. Mineralized rock identified at the surface during field work is of very limited extent. Anomalous concentrations in the geochemical data are probably a consequence of lithologies present in the sampled drainage basins and do not reflect the presence of mineralized rock. Geophysical data do not indicate the presence of mineral deposits; nor are geologic settings favorable for their occurrence. These findings suggest that the mineral resource potential for all metals in the wilderness study area is low, with level-C certainty.

Energy resources, including oil and gas, coal, uranium, and geothermal resources are unknown in the study area. The crystalline rocks that underlie the study area are neither source nor reservoir rocks for oil, gas, or coal; nor is the structural setting of the study area appropriate to undiscovered resources of these commodities. The absence of uranium-anomalous values in the geochemical database and the failure of the aeroradiometric survey to identify anomalous uranium concentrations indicate no potential for uranium deposits in the study area. The absence of geothermal phenomena and the old age of the rocks in the study area indicate that there is no potential for geothermal energy resources. Accordingly, there is no potential (with certainty level D) for energy resources in the study area.

Available geologic, geochemical, and geophysical data indicate low potential (with certainty level C) for undiscovered industrial mineral resources in the study area.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

LOW mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is unlikely. This broad category embraces areas with dispersed but insignificantly mineralized rock as well as areas with few or no indications of having been mineralized.

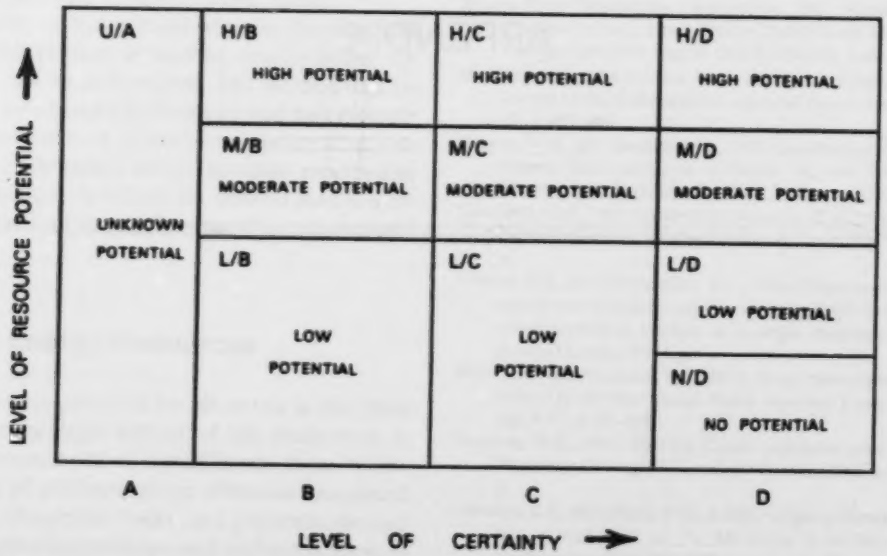
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

HIGH mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

NO mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

Levels of Certainty



A. Available information is not adequate for determination of the level of mineral resource potential.
B. Available information suggests the level of mineral resource potential.
C. Available information gives a good indication of the level of mineral resource potential.
D. Available information clearly defines the level of mineral resource potential.

Abstracted with minor modifications from:

Taylor, R. B., and Steven, T. A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

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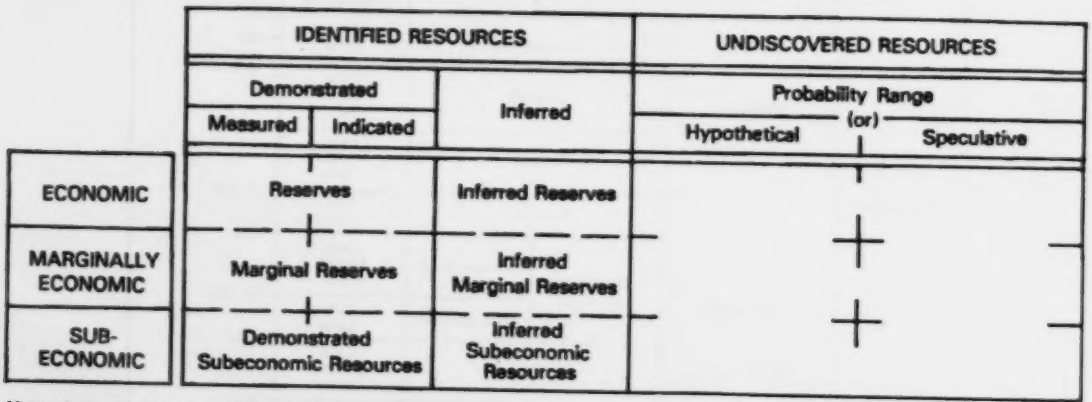
RESOURCE/RESERVE CLASSIFICATION



Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from McKelvey, 1972, Mineral resource estimates and public policy: American Scientist, v.60, p.32-40, and U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p.5.

GEOLOGIC TIME CHART

Terms and boundary ages used in this report

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late Early	96 138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~ 240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~ 330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~ 570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				
pre-Archean[2]		3800?			4550

[1] Rocks older than 570 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

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